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*Report*

# Arctic study of tropospheric aerosol and radiation, ASTAR 2000-field plan

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***Abstract:*** A new German-Japanese cooperative project on aerosols in the Arctic, ASTAR 2000 (Arctic Study of Tropospheric Aerosol and Radiation) is to be carried out in March and April 2000 in the high Arctic region (vicinity of Svalbard). The goal of the project is to investigate the behavior, properties and radiative forcing of tropospheric aerosols in the Arctic with special focus on the "Arctic Haze".

Airborne observations of vertical distribution of physical, chemical and optical properties of aerosols will be performed using Dornier 228 aircraft of Alfred-Wegener Institute for Polar and Marine Research. Extinction coefficients will be measured by sunphotometer. *In-situ* measurements and sampling of aerosols will also be made. Fifteen flights with about 75 flight hours are planned to be conducted based at Longyearbyen airport (78°N, 15°E) during March 15 and April 25, 2000.

Coordinated remote sensing by lidar and photometers, *in situ* measurements and sampling of aerosols will be done at the surface at Ny-Ålesund Scientific Station (78°55′N, 11°56′E), Svalbard. Also, balloon-borne aerosol sondes will be launched. Data are compared with the SAGE II (Stratospheric Aerosol and Gas Experiment) satellite measurements. These data will be used as input parameters for an Arctic regional climate model to calculate the radiative forcing of aerosols and to subsequently study their climatic impact.

## 1. Introduction

The polar regions are receiving increased attention in climate change scenarios obtained from climate models. This attention arises from the "polar amplification" of the surface warming in simulations with increased concentrations of greenhouse gases. The zonally averaged warming in the Arctic is two or three times larger than the global warming for a doubling of $CO_2$ (Randall *et al.*, 1998; IPCC, 1996). The enhanced warming in high latitudes is partly attributable to the retreat of sea ice, which is accelerated by the positive feedback between temperature and surface albedo (Walsh and Chapman, 1998). Recently, large variations in many climate parameters have been found in the "Changing Arctic" (Morison *et al.*, 1998; Heintzenberg, 1989). Warming of the air temperature near the surface is clearly observed, especially over the continent (Chapman and Walsh, 1993), and thinning of sea ice in the 1990s is reported for a wide area of the Arctic Ocean (Rothrock *et al.*,

1999).

Aerosols, together with clouds, are believed to have a strong impact on climate through the radiative effect with a large spatial variability; however, their 3-D distribution and interactions are still uncertain, especially in the polar regions. In the Arctic, concentrations of normal background aerosols are very low and optical thickness in the 500 nm range is in the range 0.03 to 0.05 (Herber *et al.*, 1996). However, strong seasonal variations in aerosol optical depth are known and the large spring increase is due to high concentrated layered aerosols called "Arctic Haze" (Shaw, 1995; Herber *et al.*, 1996). This large spring maximum of aerosol loading is originated from anthropogenic sources surrounding the Arctic, and trapped a long time in the strong inversion layer over the Arctic Ocean without any effective removal process (Shaw, 1995). Though this is only a seasonal phenomenon, its radiative effect is not negligible, because solar radiation becomes effective just in this season after the long polar night and a large influence might be expected related to the melting and decay of sea ice. Many observational studies have been devoted to the Arctic Haze (Bodhaine and Dutton, 1993; Jaeschke *et al.*, 1999); however, not so much has been done concerning the radiative effect yet.

Radiative forcing of atmospheric aerosols has been investigated by using very simplified models of aerosol optical properties. In this stage, the aerosol data used have been based on the Global Aerosol Data Set (GADS), see Koepke *et al.* (1997), which only considered the total aerosol optical depths and a homogeneous distribution of aerosols for the whole Arctic region. Simplified studies of radiative forcing for the Arctic Haze periods have provided a qualitative evidence of aerosol impact. Nevertheless these results have already shown that aerosols might have a significant impact on radiative forcing processes in the troposphere. Unfortunately, consistent data records are not yet available for all regions and areas of interest.

A new cooperative project on aerosols in the Arctic, ASTAR 2000 (Arctic Study of Tropospheric Aerosol and Radiation) is planned for March and April 2000 in and around Svalbard to investigate the 3-D behavior and radiative effects of tropospheric aerosols in the Arctic and their impact on climate. Airborne observations of vertical distributions of physical, chemical and optical properties of aerosols will be made around Svalbard using a Dornier 228 aircraft (Polar 4) of Alfred-Wegener Institute for Polar and Marine Research operated from Longyearbyen airport. Also, coordinated remote sensing of aerosols, *in-situ* measurements and sampling of aerosols will be done at the international research site, Ny-Ålesund, Svalbard (Fig. 1). At this site, scientists from several countries including German and Japanese scientists have already conducted ground based atmospheric science observations for about 10 years (Gernandt *et al.*, 2001; Yamanouchi *et al.*, 1996). Satellite measurements of SAGE-II (Stratospheric Aerosol and Gas Experiment) are also included as part of the ASTAR 2000 campaign. Finally, data will be used as input for regional climate model studies (HIRHAM) to estimate radiative forcing and discuss the climatic impact of aerosols in the Arctic atmosphere.

The project is co-organized by the National Institute of Polar Research (NIPR) and Alfred-Wegener Institute for Polar and Marine Research (AWI), with participants from Hokkaido University, Nagoya University, NASA Langley Research Center, Norwegian Institute for Air Research (NILU), Meteorological Institute of Stockholm University (MISU), Norwegian Polar Institute (NP), National Oceanic and Atmospheric Administra-

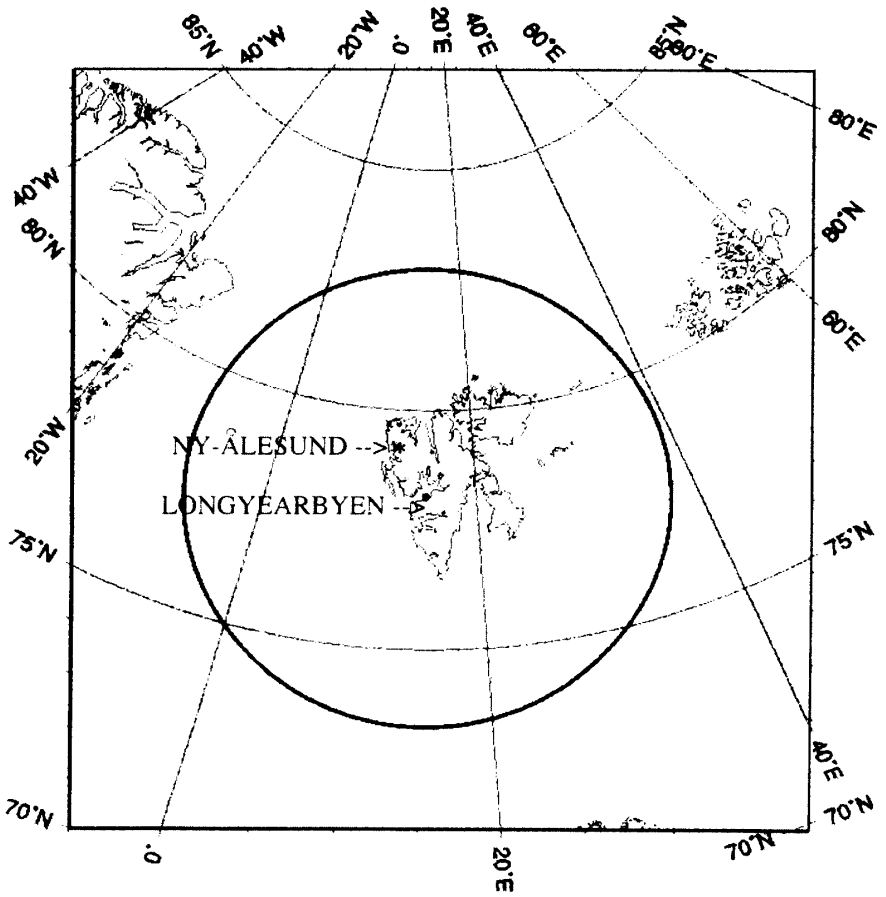
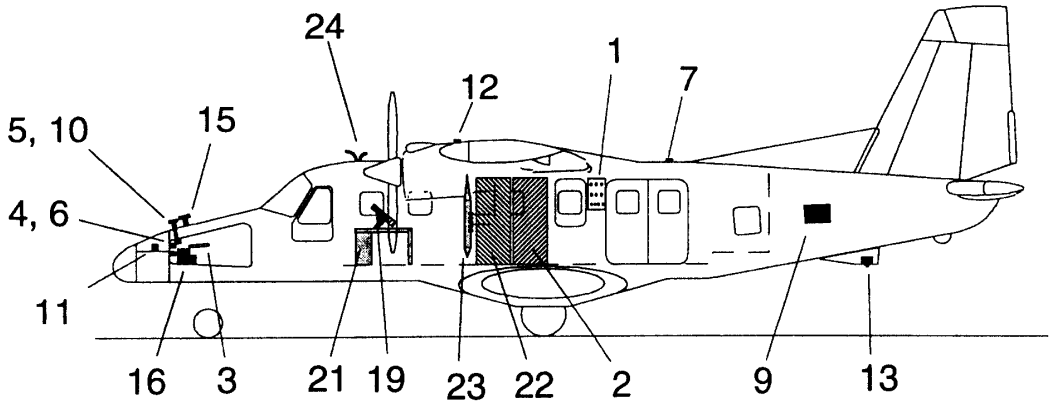



*Fig. 1. Map showing the ground-based observation site, Ny-Ålesund, and base of airborne observation, Longyearbyen. Also shown is a circle with maximum flight radius.*

tion (NOAA), Max Planck Institute for Aeronomie (MPAe) and with contributions from German Aerospace (DLR) and Aerodata Braunschweig (AD).

## 2. Airborne observations

Airborne observations using Dornier 228 aircraft of Alfred-Wegener Institute for Polar and Marine Research (AWI) are to be the crucial experimental part of the project. A sunphotometer will be used for the measurement of solar radiance to derive optical depth and extinction coefficients, and also for the measurement of sky brightness in the almucanter plane to derive the scattering phase function. The sunphotometer will be installed in the plane on a solar tracker behind a quartz window, which was prepared specially for optical measurements. The sunphotometer is to be adjusted to the direction of the sun, 80 degrees apart from the plane heading and the solar height should be between 15° to 7° for the extinction measurement. By rotating the heading of the air plane 180 degrees, horizontal scan for brightness measurement in the same zenith angle will be made. Downward and upward shortwave and longwave radiation fluxes will be measured by broad band radiometers settled on the roof and bottom of the plane. *In-situ* measurements of aerosols




Basic Equipment:
1 Central Data Interface
2 Rack
3 Pitot Tube
4 Pressure Transducer
5 Temperature Sensor
6 Electrical Distribution
7 GPS Antenna
9 INS

Humidity Sensor System:
10 Humidity Sensor
11 Signal Amplifier

Radiation Sensors:
12 Pyranometer and Pyrgeometer Top
13 Pyranometer and Pyrgeometer Bottom

Dew Point Mirror:
15 Sensor
16 Power Supply and Control Units

Sun Photometer:
19 Photometer Unit
21 Photometer Desk

NIPR Systems:
22 Rack with Instruments
23 Diffuser
24 Air Inlet

*Fig. 2. Instrumentation of Polar 4 for ASTAR 2000 campaign.*

are to be made; particle size distribution, absorption and scattering coefficients will be measured by optical particle counters (OPCs), a particle soot absorption photometer (PSAP) and an integrating nephelometer (IN), respectively. Aerosols will also be sampled with a low volume filter sampler and aerosol impactor to conduct chemical analyses and electron microscope analyses. As shown in Fig. 2, air is introduced to the diffuser from the intake settled at the roof of the plane, and then guided to each instrument. Data from all the instruments are to be recorded in a central data recorder together with flight information and basic meteorological parameters such as pressure, temperature, relative humidity, dew point and wind velocity.

Using Longyearbyen airport (78°N, 15°E) as the operational base, 16 flights with about 80 flight hours were scheduled for the period from March 15 until April 25, 2000. The aircraft observations consist of three phases: phase I for special closure observations with ground based observations at Ny-Ålesund, phase II for the haze observations and phase III for comparison with SAGE II satellite observations. Those flights will be made in small target areas depending on the objective within about 500 km from Longyearbyen, as shown in Fig. 1. In the target area, a vertical profile from near the surface up to 8 km is to be measured with the level flight at 1 km altitude intervals.

## 3. Ground-based and *in-situ* observation

The airborne measurements are complemented by comprehensive ground-based measurements, providing such crucial aerosol parameters as phase fuction and absorption coefficients as a function of height. Coordinated ground-based remote sensing, *in-situ* measurements, sampling and balloon-borne observations of aerosols will be performed at the surface, at the international research site, Ny-Ålesund (78.95°N, 11.93°E; Fig. 1).

In 1991, regular measurements of aerosols commenced at Ny-Ålesund. Since then observations have been improved and extended by newly developed instruments, such as sun and star photometers, to retrieve the aerosol optical depth and phase function in the visible and near infrared spectral range, the tropospheric Raman-lidar to measure extinction coefficients and depolarization as a function of altitude, and the Fourier transformed infrared spectrometer (FTIR) to calculate the aerosol optical depth in the IR spectral range by measuring emission spectra. Additional new systems are a micropulse lidar for backscatter measurement and sky radiometers for extinction and phase function measurements.

*In-situ* measurements will be made by optical particle counters (OPCs), integrating nephelometer and particle mobility analyzer. Ground sampling of aerosols will be done by high volume and low volume samplers and an aerosol impactor. Balloon-borne aerosol sondes with OPC will be launched and a tethered balloon with OPC will be used to obtain the vertical distribution of aerosol particle concentration in the atmosphere close to the surface. Supporting data will be include surface ozone measured by Dasibi ozone meter, precipitable water amount and liquid water content by microwave radiometer, precipitation by POSS, surface radiaitive fluxes by BSRN (Baseline Surface Radiation Network) radiometers and aerological soundings. At the Zepelin mountain station (470 m a.s.l.), *in-situ* measurements and samplings of aerosols will also be made.

## 4. Satellite observations and model studies

SAGE-II (Stratospheric Aerosol and Gas Experiment) satellite observations of stratospheric aerosols are used to separate the tropospheric contribution from total atmospheric aerosol burden and provide information on spatial distributions in the Arctic region (McCormick, 1987). Also, satellite extinction measurement will be validated from airborne measurement data. A combination of all of these methods is recently used to obtain as much information as possible on temporal and vertical distributions of atmospheric aerosols and their optical properties.

For detailed model studies it is necessary to provide data on the temporal and spatial—in particular—vertical distribution of aerosols. Furthermore, optical parameters such as spectral optical depth, extinction coefficient, absorption coefficient, and phase function have to be measured. For all of these parameters a large number of different methods and instruments are used, including satellite information, like SAGE-II. There is not yet a clear understanding of the impact of tropospheric aerosols on radiative forcing processes in the Arctic. All these aerosol data will then be incorporated in to the HIRHAM Arctic regional climate model (Dethloff *et al.*, 1996) for detailed model studies on the direct radiative forcing of Arctic tropospheric aerosols.

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